THE MASSACHUSETTS TOXICS USE REDUCTION INSTITUTE

Massachusetts Chemical Fact Sheet

Trichloroethylene (TCE)

TCE is a probable carcinogen and a possible teratogen (reproductive hazard). Slow to degrade in groundwater, TCE has been a contaminant in drinking water. In Massachusetts, facilities use TCE to degrease metal, to produce solvent mixtures, and as a solvent for adhesives. Reflecting the availability of safer substitutes and increasingly stringent regulations, TCE use is on the decline in Massachusetts.

FACTS

Common Name:	TCE
Chemical Formula:	C_2HCl_3
CAS Number:	79-01-6
Vapor Pressure:	69 mm Hg, 25°C
Flash point:	90 °F
Water Solubility:	slightly soluble
Odor:	sweet odor
Appearance:	clear liquid

Hazards

Acute Toxicity

- At exposure levels around 1,000 ppm, TCE can be lethal.
- The primary acute effects of TCE are on the central nervous system, kidney, and liver. Inhalation of TCE can cause dizziness, unconsciousness, an irregular heart beat, brain damage, and memory loss.
- Once thought to be safe, TCE was used as an anesthetic for surgery until the U.S. Food and Drug Administration banned that use in 1976.

Chronic Toxicity

- TCE is a suspected human carcinogen. The International Agency for Research on Cancer Classification (IARC) classifies TCE as a Group 2A carcinogen — a probable carcinogen — because it has been shown to cause liver cancer in animals.
- Until further testing is done, TCE should be treated as a teratogen because some studies have found an association between exposure to solvents that include TCE and birth defects among women in the shoemaking industry.[1]

Chronic exposure to TCE, perchloroethylene and other solvents through contaminated drinking water is also the suspected cause of many adverse health effects experienced by residents in Woburn, Massachusetts, between 1970 and 1985. Woburn parents that drank, showered, and bathed in contaminated water gave birth to a higher than average number of children who suffered birth defects (including cardiac abnormalities), increased rates of urinary tract infections, and increased rates of leukemia.[2] Another study documented a measurable slowing in blink reflex (suggesting nerve damage) in Woburn residents who drank TCE-contaminated water.[3] However, other chemicals were present in water from these wells and it has been impossible to ascertain whether these chemicals were indeed the cause of the problems suffered by the community residents.

This is one in a series of Massachusetts Chemical Fact Sheets prepared for each of the chemicals in significant use on the Toxics Use Reduction Science Advisory Board's 'more hazardous chemicals' list. For more information on the Chemical Categorization Project, consult TURI Technical Report #47.

Exposure Routes

Worker Health

Facilities using TCE need to minimize worker exposure by enclosing operations and using local exhaust ventilation. Ideally, TCE should be automatically pumped from storage to process containers. Outside the daily routine, leaks and fires pose the greatest threat to workers. While TCE is only slightly flammable, during fires it can mix with other chemicals and air to form poisonous gases such as phosgene and hydrogen chloride. To minimize the potential for fires, TCE should be stored away from high temperature operations and materials. Also, to prevent violent reactions, explosions, and the formation of highly flammable toxic liquids TCE should be stored away from strong alkalis, aluminum in the presence of dilute hydrochloric acid, and chemically active metals, powders, or shavings.[4]

Public Health Exposure

Drinking water has been the primary source of public exposure to TCE. A 1993 national assessment of groundwater studies revealed TCE in 16% of all the samples analyzed. Other sources of TCE exposure include food and household products. TCE bioconcentrates in fish tissue, some 2-39 times higher concentrations in fish tissue than in the surrounding water, and has also been detected in grains and dairy products.[5] A variety of consumer products contain TCE, including some typewriter correction fluids, paint removers, strippers, adhesives, spot removers, and rug-cleaning fluids.

In the air, TCE degrades to phosgene, trichloroacetic acid, dichloroacetyl chloride, formyl chloride and other compounds (the half-life of TCE is seven days). Generally, airborne exposure is low unless an individual works with or lives near a facility using TCE.

Use Nationally and in Massachusetts

The two U.S. manufacturers of TCE are the Dow Chemical plant in Texas and PPG Industries plant in Louisiana. In 1998, these two plants had the capacity to produce 320 million pounds of TCE per year.[6] Nationally, metal cleaning is the dominant end use for TCE; it accounted for 56% of all U.S. consumption in 1996. Other uses of TCE are as a precursor in the formation of halogenated fluorocarbons (HFCs, 40%), and in the manufacture of PVC and adhesives. TCE production increased 64% between 1990 and 1996 because of its use as a precursor in HFC production.

In Massachusetts, reported TCE use is not following the upward national trend because manufacturers in the state are investing in safer substitutes and do not produce HFCs.

- TCE reported use declined 10% between 1990 and 1996, dropping from 3.7 to 3.3 million pounds (see Table 1).

- TCE use by manufacturers actually declined by much more than 10%, however in 1991 chemical distributors were added to the list of industries that report under the Massachusetts Toxics Use Reduction Act (MA TURA) and began reporting 1.3 million pounds of use. In 1996 chemical distributors reported 1.2 million pounds of use.

- TCE use in adhesives and chemical products (other than chemical distributors) decreased 43% from 1990 to 1996.

- The use of TCE as a degreaser of metals and electronic components declined 55% between 1990 and 1996, dropping from 2.13 to 0.97 million pounds (Table 2).

Table 1 includes two sources of "output" data: MA TURA and U.S. Environmental Protection Agency (EPA), Toxics Release Inventory (TRI) data. The MA TURA database includes all non-product material created by a process line prior to release, on-site treatment, or transfer ("byproduct") and the amount of toxic chemical incorporated into a product ("shipped in or as product"). The EPA, TRI database includes information on the waste materials generated by a facility after on-site treatment: including releases to air, land, and water ("environmental releases") and transfers off-site for treatment or disposal ("off-site transfers").

Table 1: Massachusetts Trichloroethylene Data Inputs and Outputs for 1990 and 1996

Inputs -- MA TURA	Inputs (pounds) 1990	1996	Change in Inputs (pounds)	% Change
Manufactured or Processed	1,215,555	1,885,823	670,268	55%
Otherwise Used	2,435,672	1,409,442	-1,026,230	-42%
Total Inputs	**3,651,227**	**3,295,265**	**-355,962**	**-10%**
Outputs -- MA TURA	**Outputs (pounds) 1990**	**1996**	**Change in Outputs (pounds)**	**% Change**
Generated as Byproduct	2,389,120	1,086,372	-1,302,748	-55%
Shipped In/As Product	1,129,237	2,262,727	1,133,490	100%
Total TURA Outputs	**3,518,357**	**3,349,099**	**-169,258**	**-5%**
Releases and Transfers (R&T) -- EPA	**R&T (pounds) 1990**	**1996**	**Change in R&T (pounds)**	**% Change**
Environmental Releases	1,309,690	719,703	-589,987	-45%
Off-site Transfers	194,782	640,603	445,821	229%
Total EPA R&T	**1,504,472**	**1,360,306**	**-144,166**	**-10%**

Sources: MA TURA -- Massachusetts Toxics Use Reduction Act data, 1998; and EPA -- US Environmental Protection Agency, Toxics Release Inventory data, 1998.

- TRI releases to the environment dropped 590,000 pounds, or 45%, from 1990 to 1996, while off-site transfers increased by 445,000 pounds.

- MA TURA outputs declined 5% between 1990 and 1996. This was due to a dramatic decline in byproduct generation (55%) and an increase in TCE shipped in product, mostly by the chemical distributors who began reporting in 1991.

Alternatives

One alternative for TCE as a degreaser is to redesign the production process to eliminate the need for cleaning. This may be accomplished by redefining cleanliness specifications, eliminating the process step that results in a dirty part or changing the nature of the soil to eliminate the need for cleaning (e.g., vanishing machining oils). In the electronics industry, fluxless, low-flux and water-soluble flux systems are available which eliminate or at least alleviate the cleaning burden.

When cleaning is necessary, many alternatives to TCE exist. The two most popular alternatives are aqueous and semi-aqueous systems. Positive environmental aspects of the aqueous and semi-aqueous alternatives are that workers are not exposed to solvents, less hazardous solid waste is produced and emission control is not necessary. In addition to aqueous and semi-aqueous systems, there are non-chlorinated solvent systems, mechanical cleaning processes (e.g., abrasive blasting) and other emerging cleaning technologies (e.g., laser cleaning).

The Toxics Use Reduction Institute's Surface Cleaning Laboratory assists companies in finding cost effective alternatives to solvent cleaning systems while maintaining product quality. One example of successful replacement of a TCE vapor degreaser is a Massachusetts precision machine shop that installed an aqueous ultrasonic system to remove silicon carbide lapping oil from parts. While the aqueous cleaning process resulted in more time required to clean the parts, this was acceptable to the

Table 2. Massachusetts Trichloroethylene Use by Use Categories for 1990 and 1996[7]				
Use Categories	Facility Name	Trichloroethylene Use (pounds) 1990	1996	% Change
Adhesive Lamination	Shawmut Mills	302,000	444,000	47%
	Total	302,000	444,000	47%
Chemical Products and Distribution	Ashland Chemical Co.	0	130,463	n/a
	Astro Chemicals Inc.	0	325,660	n/a
	Camger Chemical	0	37,851	n/a
	CL Hauthaway & Sons	0	38,000	n/a
	Creative Chemicals	158,600	0	-100%
	General Chemical Corp.	0	747,560	n/a
	Laidlaw Chemical	824,547	289,772	-65%
	Shield Packaging	24,845	37,312	50%
	TACC International	207,563	279,205	35%
	Total	1,215,555	1,429,700	18% [3]
Degreasing Metals	Acushnet Rubber	12,761	16,140	26%
	Adtec Electroplating	0	14,019	n/a
	American Electroplating	16,555	0	-100%
	Anderson Sons	20,250	0	-100%
	Automatic Mach	28,000	20,040	-28%
	Brittany Dyeing & Printing	0	16,800	n/a
	Cambridge Plating	97,600	121,787	25%
	Duncan Group, The	0	34,764	n/a
	Duralectra	19,874	12,300	-38%
	Federal Metal Finishing	12,100	0	-100%
	Fountain Plating	0	14,520	n/a
	Gillette	212,524	0	-100%
	Industrial Blast Coil Corp.	58,829	0	-100%
	JH Smith	15,404	0	-100%
	Krew, Inc.	0	23,844	n/a
	LE Mason Company	61,105	0	-100%
	Lee Products	0	14,637	n/a
	Lightolier/Fall River	157,571	0	-100%
	LS Starrett	0	38,940	n/a
	Lytron	0	12,540	n/a
	Modern Electroplating	48,000	0	-100%
	National Perforating Corp.	13,000	0	-100%
	New England Newspaper	16,528	0	-100%
	New Method Plating	66,700	21,776	-67%
	Peter Gray	19,073	0	-100%
	Plating for Electronics	0	12,464	n/a
	Robbins	21,819	0	-100%
	Standard Thomson	14,520	0	-100%
	Stern Leach Company	70,984	49,803	-30%
	Swank	16,088	0	-100%
	U.S. Ring Binder Corp.	56,800	0	-100%
	Valentine Tool and Stamping	54,856	0	-100%
	Walbar Metals	0	21,857	n/a
	Whiting and Davis	21,943	0	n/a
	Total	1,132,884	446,231	-61%
Degreasing Electronics	Aerovox	322,800	206,800	-36%
	Commonwealth Sprague	0	10,560	n/a
	Cornell Dubilier	60,977	0	-100%
	EG&G	15,630	0	-100%
	Gould Electronics	29,760	23,940	-20%
	International Equipment Corp.	23,764	0	-100%
	M/A Com	28,122	16,562	-41%
	Raytheon Company	60	0	-100%
	Raytheon Power	24,255	0	-100%
	Sprague North Adams	77,000	0	-100%
	Tech Etch	15,683	11,349	-28%
	Texas Instruments	381,000	250,000	-34%
	VH Blackington	21,737	0	-100%
	Total	1,000,788	519,211	-48%
	Total Trichloroethylene Use	**3,651,227**	**3,295,265**	**-10%**

company and the quality of the cleaning was equal to the vapor degreasing process.

In adhesive formulations, alternatives to TCE are available, including terpenes, water-based adhesives, and solid adhesives (hot melts). The costs and benefits of making these conversions are difficult to generalize because each adhesive use is unique.

Regulatory Context

TCE is regulated throughout its lifecycle: in the type of uses allowed, in the workplace, in its release to the environment from workplaces, and in its disposal. Because of its toxicity, many uses of TCE are forbidden in the U.S. The U. S. Food and Drug Administration has banned the use of TCE in food processes, as an anesthetic in surgery, and in the processing of cosmetics and drug products. Sweden has gone one step further and is phasing out all uses of TCE.

In the workplace environment, the Occupational Safety and Health Administration set two exposure levels for TCE: the permissible exposure level (PEL) for TCE, averaged over an 8-hour workshift, is 100 ppm and the short-term exposure limit for TCE is 200 ppm.

The U.S. EPA regulates TCE under authority of many statutes, including the Clean Air Act, Safe Drinking Water Act, and Resource Conservation Recovery Act.

- Under authority of the Clean Air Act, the US EPA requires users of vapor degreasers to meet the national emission standard for hazardous air pollutants (NESHAPs) for halogenated solvent cleaners. TCE is a halogenated solvent. Facilities can comply with the NESHAP by installing control equipment and automated parts handling, complying with an idling emission limit and installing automated parts handling, or complying with a total emissions limit.

- The "maximum contaminant level" (MCL) for TCE in drinking water is 5 parts per billion. The MCL is the maximum permissible level of a contaminant in drinking water from a public water system. The U.S. EPA sets the MCL under authority of the Safe Drinking Water Act.

- The U.S. EPA banned the land disposal of TCE under authority of the Resource Conservation and Recovery Act. In fact, no chlorinated solvent wastes can be legally landfilled in the U.S.; rather they must be destroyed in incinerators or cement kilns.

References

ATSDR, 1993. Agency for Toxic Substances and Disease Registry (ATSDR). "Toxicological Profile for Trichloroethylene" (PB93-182533). Washington, D.C.: U.S. Department of Health and Human Services.

Becker, Monica and Ken Geiser. *Evaluating Progress: A Report on the Findings of the Massachusetts Toxics Use Reduction Program Evaluation.* Lowell, MA: Toxics Use Reduction Institute, University of Massachusetts Lowell.

Environmental Protection Agency. September 1994. "The Product Side of Pollution Prevention: Evaluating the Potential for Safe Substitutes." (EPA/600/R-94/178). Washington, D.C.

Environmental Protection Agency, November 15, 1994. Final Air Toxics Rule for Halogenated Solvent Cleaning Machines. http://www.epa.gov/reg3artd/enforce/toxics/dsdegrea.html.

Feldman, 1998. Feldman, Robert, et al. "Blink Reflex Latency After Exposure to Trichloroethylene in Well Water." *Archives of Environmental Health*, March/ April, Vol. 43, No. 2.

Geiser, Ken and Mark Rossi. 1995. *Toxic Chemcial Management in Massachusetts: The Second Report on Further Chemical Restriction Policies.* Lowell: Toxics Use Reduction Institute, University of Massachusetts Lowell.

Harriman and Hart, 1996. Harriman, Elizabeth and Maureen Hart. *Measuring Progress in Toxics Use Reduction and Pollution Prevention.* Lowell, MA: Toxics Use Reduction Institute, University of Massachusetts Lowell.

Howard, et al, 1990. Howard, Philip H., et al. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals: Volume II B Solvents.* Chelsea, Michigan: Lewis Publishers.

KemI, 1995. Swedish National Chemicals Inspectorate (KemI). *Chlorine and Chlorinated Compounds: Survey of Fluxes to and in the Environment, Pools in the Environment and Health and Environmental Risks* (Report No. 5/95). Solna, Sweden: KemI.

KemI, 1991. Swedish National Chemicals Inspectorate. *Risk Reduction of Chemicals: A Government Commission Report.* Stockholm: Sweden.

Lagakos, et al, 1986. Lagakos, S.W., B.J. Wesson, M. Zelen, et al. "An Analysis of Contaminated Well Water and Health Effects in Woburn Massachusetts." *Journal of the American Statistical Association*, vol. 81:583-614.

Lewis, 1996. Lewis, Richard J. *Sax's Dangerous Properties of Industrial Materials* (9th edition). New York: Van Nostrand Reinhold.

MassPIRG. 1986. Massachusetts Public Interest Research Group. *Hazardous Waste in Our Drinking Water.* Boston: MassPIRG.

NJDOH, 1992. New Jersey Department of Health (NJDOH). "Trichloroethylene." Trenton, New Jersey: NJDOH (also see the webpage: http://www.rtk.net/E1417T29).

SRI. Stanford Research Institute (SRI). *Chemical Economics Handbook* (updated annually). Palo Alto, California: SRI.

TURI (Toxics Use Reduction Institute) and the Office of Technical Assistance for Toxics Use Reduction. March 1997. *Guidebook of Part Cleaning Alternatives.* Lowell, Massachusetts.

Endnotes

1 NJDOH, 1992.
2 Lagakos, et al, 1986.
3 Feldman, et al, 1988.
4 NJDOH, 1992.
5 Howard, et al, 1990.
6 All national data are from SRI, 1999.
7 Source: Massachusetts Toxics Use Reduction Act data, 1998; Use Categories were assigned based on TURA production unit descriptions, which were not specifically intended for this use. The final categories do not necessarily represent the manufacturers' descriptions of their use; n/a = not applicable; The total for Chemical Products and Distribution does not accurately reflect the change in this category because Chemical Distributors were required to report under TURA beginning in 1991.